

# LORENZ FIELDS CONVEY ENERGY AS NADELSTRAHLUNG

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**ABSTRACT.** Gauge transformations leave unchanged only specific Maxwell fields. To reveal more, I develop Lorenz field equations for superposed, sourced and unsourced, wave function potentials. In this Maxwell form system, the Lorenz condition is charge conservation. This allows me to define three transformation classes that screen for Lorenz relevance. Nongauge, sans gauge function, Lorentz conditions add polarization fields. These enable emergent, light-like radiation. That from Lissajous potentials is Nadelstrahlung. It conveys energy localized like particles at charge conserving, progressive phase points. Such rays escape discovery in modern Maxwell fields where gauge transformations suppress the polarizations.

## 1. INTRODUCTION

In 1867, during the time when J. C. Maxwell (1831-79) was publishing his electromagnetic theory, L. V. Lorenz (1829-91) published his theory equating light vibrations with electric currents [1]. This work is translated to modern vector notation and critiqued in [2]. Lorenz starts with Kirchhoff's Ohm's law expression. For scalar potentials with a finite propagation speed, he obtains delayed potentials. These potentials satisfy inhomogeneous wave equations and, when charge is conserved, the eponic Lorenz condition [3, pp. 268-9]. They are nonlocal. All their derivatives also must be inhomogeneous wave function solutions for correspondingly differentiated remote sources. Since the potentials satisfy wave equations they can be augmented with homogeneous wave equation solutions. These sourceless augmentations are local. Their derivatives depend only on proximate values. The composite potentials still satisfy wave equations and the Lorenz condition with one and the same propagation speed. But they are no longer strictly delayed. Their differential character is mixed, local and nonlocal.

In his 1867 paper, Lorenz never develops first order field equations from his potentials. In fact, until now, this has been ignored. With magnetic induction as the vector potential curl, I obtain Lorenz field equations with Maxwell form. This allows Lorenz delay to be fully probed. For nonlocal potentials, the fields in these equations are nonlocal also. The desirable locality can be restored as a far field approximation for systems that satisfy specific size constraints [4, p. 222]. For the augmented potentials, the Lorenz field equations incorporate fields for electric displacement and magnetic field strength by adding polarization fields. This development is presented formally in Sec. 2. It shows that wave function potentials satisfying the Lorenz condition assure charge conservation. Thus, the form invariant Lorenz condition is charge conservation. This limits potentials transformation. Polarization radiation is described in Sec. 3. It should aid light mechanism study. Transformation and radiation aspects are discussed in Sec. 4.

## 2. LORENZ FIELDS

The electromagnetic Lorenz potentials satisfy differential wave equations with charge,  $\rho$ , and current,  $\mathbf{J}$ , density sources and, when charge is conserved, the Lorenz condition

$$-a\nabla \bullet \mathbf{A} = \frac{\partial \Omega}{\partial t}. \quad (1)$$

For sources distributed throughout all space, the potentials are given by

$$\square_a \Omega = -4\pi\rho, \quad (2a) \quad a\square_a \mathbf{A} = -4\pi\mathbf{J}. \quad (2b)$$

The wave equation operator for wave speed  $a$ ,  $\square_a$ , is defined in Sec. 4.1. When the potentials are augmented by solutions to the homogeneous wave equation,  $\square_a \Omega_0 = \square_a \mathbf{A}_0 = 0$ , the Lorenz condition takes the modified form

$$-a\nabla \bullet (\mathbf{A} + \mathbf{A}_0) = \frac{\partial(\Omega + \Omega_0)}{\partial t}. \quad (3)$$

The augmentations could be set to zero by implicit scalar strengths. For

$$\mathbf{E} = -\nabla\Omega - \dot{\mathbf{A}}/a \quad (4a) \quad \text{and} \quad \mathbf{B} = \nabla \times \mathbf{A}, \quad (4b)$$

we also have the fields  $\mathbf{D} = \mathbf{E} + \mathbf{P}$  and  $\mathbf{H} = \mathbf{B} - \mathbf{M}$ . The polarization fields are

$$\mathbf{P} = -\nabla\Omega_0 - \dot{\mathbf{A}}_0/a \quad (5a) \quad \text{and} \quad \mathbf{M} = -\nabla \times \mathbf{A}_0. \quad (5b)$$

The ring denotes temporal partial differentiation. Constants for units adjustment are set to unit value. All fields satisfy wave equations with propagation speed  $a$ . These definitions pass the augmentation strengths to the polarizations. Without strengths, the polarizations vanish when the augmentations are derived from a gauge function, *i.e.* when  $\mathbf{A}_0 = \nabla\chi$  and  $\Omega_0 = -\dot{\chi}/a$ . The fields satisfy Maxwell form equations:

$$\nabla \bullet \mathbf{B} = 0, \quad (6a) \quad \nabla \bullet \mathbf{D} = 4\pi\rho, \quad (6b)$$

$$a\nabla \times \mathbf{E} = -\partial\mathbf{B}/\partial t, \quad (6c) \quad a\nabla \times \mathbf{H} = \partial\mathbf{D}/\partial t + 4\pi\mathbf{J}. \quad (6d)$$

Together Eqs. (6b) and (6d) give the condition for charge conservation

$$\nabla \bullet \mathbf{J} + \frac{\partial \rho}{\partial t} = 0. \quad (7)$$

The Eq. (3) Lorenz condition too gives this when acted on by the wave equation operator  $\square_a$ .

Fields derived from the delayed potentials can not be proportional to those derived from the potential augmentations. This means coupling normally provided by the constitutive relations,  $\mathbf{D} = \epsilon\mathbf{E}$  and  $\mathbf{B} = \mu\mathbf{H}$ , is not primal. There are three choices. First, take the relations as valid in very small space-time volumes where boundary conditions are set. Second, further augment the potentials with proportional delayed potentials. Then, wave function speed can be adjusted for dielectric constant  $\epsilon$  and magnetic permeability  $\mu$  by measurement. Third, couple the fields by local and nonlocal fluxes. To see this, notice that the relation  $\mathbf{H} \bullet (\nabla \times \mathbf{D}) - \mathbf{D} \bullet (\nabla \times \mathbf{H}) = \nabla \bullet (\mathbf{D} \times \mathbf{H})$  allows two energy continuity expressions to be obtained from Eqs. (6c) and (6d). When  $\mathbf{E}$  and  $\mathbf{B}$  are replaced by  $\mathbf{P}$  and  $\mathbf{M}$  using the expressions for  $\mathbf{D}$  and  $\mathbf{H}$ ,

$$a\nabla \bullet (\mathbf{H} \times \mathbf{D}) = \left[ \mathbf{H} \bullet \frac{\partial \mathbf{H}}{\partial t} + \mathbf{D} \bullet \frac{\partial \mathbf{D}}{\partial t} \right] + 4\pi\mathbf{D} \bullet \mathbf{J}. \quad (8a)$$

More directly,

$$a\nabla \bullet (\mathbf{H} \times \mathbf{E}) = \left[ \mathbf{H} \bullet \frac{\partial \mathbf{B}}{\partial t} + \mathbf{E} \bullet \frac{\partial \mathbf{D}}{\partial t} \right] + 4\pi\mathbf{E} \bullet \mathbf{J}. \quad (8b)$$

Both exist when the polarizations vanish. But when  $\mathbf{E}$  and  $\mathbf{B}$  vanish, the latter vanishes and the former carries the entire flux. This coupling allows local polarization waves to emerge from a nonlocal electromagnetic field. The Hertz dipole radiation solution discussed in Sec. 4.2 is the only extant example which exhibits this emergence.

### 3. POLARIZATION RADIATION

As sources go to zero the potentials become possible augmentations. So, the potential augmentations can conserve charge. These augmentations are then restrained by the Lorenz condition. Potentials in matter free space have not been so restrained previously. With this restraint, the potentials describe waves that can be considered to propagate by progressively conserving charge. Features are given in Sec. 3.1. There I show the polarizations will describe rays without the longitudinal fields that plague other formulations [5]. An example with Lissajous vector potential is presented in Sec. 3.2. In this instance rays are real space paths determined by linearly independent potential vector component phases. With neither wave packet dispersion [6] nor quantum mechanical nonlocality, these rays provide localization that has long eluded discovery. Localization to rays is relaxed for linearly dependent component phases.

**3.1. Polarization waves.** As representative Lorenz potential augmentations consider

$$\mathbf{A}_0 = (f, g, h), \quad (9a) \quad k\Omega_0 = \mathbf{k} \bullet \mathbf{A}_0 = k_x f + k_y g + k_z h. \quad (9b)$$

When  $f$ ,  $g$  and  $h$  are functionally dependent only on phase factors  $\omega t - \mathbf{k} \bullet \mathbf{r}$  where  $\mathbf{k} = (k_x, k_y, k_z)$  and  $a^2 k^2 = \omega^2$ , these potentials satisfy the homogeneous wave equation and the Lorenz condition. Since  $\nabla \Omega_0 = -\dot{\Omega}_0 \mathbf{k} / \omega$  and  $\mathbf{k} \times (\mathbf{k} \times \dot{\mathbf{A}}_0) = \mathbf{k}(\mathbf{k} \bullet \dot{\mathbf{A}}_0) - k^2 \dot{\mathbf{A}}_0$ ,

$$\omega k \mathbf{P} = \mathbf{k} \times (\mathbf{k} \times \dot{\mathbf{A}}_0), \quad (10a) \quad \omega \mathbf{M} = \mathbf{k} \times \dot{\mathbf{A}}_0. \quad (10b)$$

When the vector potential components are periodic functions they can be considered to be plane waves. Unlike Lorenz fields defined by nonlocal potentials, the polarizations are local functions. They are orthogonal,  $\mathbf{P} \bullet \mathbf{M} = 0$ , and have no longitudinal components,  $\mathbf{k} \bullet \mathbf{P} = \mathbf{k} \bullet \mathbf{M} = 0$ ; they carry a flux  $\mathbf{M} \times \mathbf{P} = \omega^{-2} (\mathbf{k} \times \dot{\mathbf{A}}_0)^2 \mathbf{k} / k$  equal to  $\mathbf{D} \times \mathbf{H}$  when  $\mathbf{E} = \mathbf{B} = 0$  and travel indefinitely in a ray direction  $\mathbf{k}$  at speed  $a$  without driving sources.

**3.2. Polarization flux localization.** Polarization waves provide, at least, a classical solution to the [7, 8, 9, 21] duality. To see how, consider a vector potential with Lissajous phases  $\phi_1 = \omega_1 t - \mathbf{k}_1 \bullet \mathbf{r}$ ,  $\phi_2 = \omega_2 t - \mathbf{k}_2 \bullet \mathbf{r}$  and  $\phi_3 = \omega_3 t - \mathbf{k}_3 \bullet \mathbf{r}$  where  $\mathbf{k}_1 = (k_{1x}, k_{1y}, 0)$ ,  $\mathbf{k}_2 = (k_{2x}, k_{2y}, 0)$  and  $\mathbf{k}_3 = (0, 0, k_{3z})$ . Though periodic components are not essential, added insight is provided by the simple form

$$\mathbf{A}_0 = (\sin \phi_1, \sin \phi_2, \sin \phi_3). \quad (11a)$$

When  $a^2 k_I^2 = \omega_I^2$  for  $I = 1, 2$  or  $3$ ,  $\square_a \mathbf{A}_0 = 0$ . The Lorenz condition gives

$$\Omega_0 = (k_{1x}/k_1) \sin \phi_1 + (k_{2y}/k_2) \sin \phi_2 + \sin \phi_3. \quad (11b)$$

This also satisfies the homogeneous wave equation  $\square_a \Omega_0 = 0$ . So these potentials can be taken to define the Eqs. (5) Lorenz polarizations and flux given in the Appendix.

When  $\phi_1 = \phi_2 = \phi$  for  $\mathbf{k}_1 \neq \mathbf{k}_2$  the phase moves on the parametric line

$$X(t) = [k_{2y}(\omega_1 t - \phi) - k_{1y}(\omega_2 t - \phi)] / (k_{1x}k_{2y} - k_{2x}k_{1y}), \quad (12a)$$

$$Y(t) = [-k_{2x}(\omega_1 t - \phi) + k_{1x}(\omega_2 t - \phi)] / (k_{1x}k_{2y} - k_{2x}k_{1y}) \quad (12b)$$

with velocity

$$\mathbf{V} = (k_{2y}\omega_1 - k_{1y}\omega_2, k_{1x}\omega_2 - k_{2x}\omega_1, 0) / (k_{1x}k_{2y} - k_{2x}k_{1y}) \quad (13)$$

giving  $V^2 = 2a^2 k_1 k_2 [k_1 k_2 - (k_{1x}k_{2x} + k_{1y}k_{2y})] / (k_{1x}k_{2y} - k_{2x}k_{1y})^2$ . If the flux vector were to have a component perpendicular to the phase velocity the ray would dissipate. So the vector product components must vanish or, for the Eqs. (17c) and (13) flux and velocity,

$$(k_{2y}\omega_1 - k_{1y}\omega_2) \left( \frac{k_{2x}k_{2y}}{k_2} - \frac{k_{1y}^2}{k_1} \right) - (k_{1x}\omega_2 - k_{2x}\omega_1) \left( -\frac{k_{1x}k_{1y}}{k_1} + \frac{k_{2x}^2}{k_2} \right) = 0. \quad (14)$$

This reduces to  $(k_{1y} + k_{2x})[k_1 k_2 - (k_{1x}k_{2x} + k_{2y}k_{1y})] = 0$ . So,  $\mathbf{k}_1$  and  $\mathbf{k}_2$  can satisfy two alternative conditions for flux and phase velocity directions to be aligned. The phase  $\phi$  is a parameter that gives simple harmonic polarizations. But  $\phi$  is not a wave phase factor unless  $\omega_1 = \omega_2$ , because it is confined to the line defined by Eqs. (12). As  $\mathbf{k}_1 \rightarrow \mathbf{k}_2$ , the ray-like character persists.

Although the case for  $\mathbf{k}_1 \neq \mathbf{k}_2$  would appear to have physical relevance in describing light-like waves, the more general case in which  $\phi_1 \neq \phi_2$  may provide a particle description for light. In this case, the phase point  $(\phi_1, \phi_2)$  moves on a path defined by Eqs. (12) with  $\phi$  replaced by  $\phi_1$  or  $\phi_2$ . Now, the flux has the Eq. (16c) form. To prevent ray dissipation by flux components normal to the phase path, restraints must again be applied to  $\mathbf{k}_1$  and  $\mathbf{k}_2$ . These will depend on  $\phi_1$  and  $\phi_2$ . This means the flux is carried by phase points. This case is illustrated in Fig. 1 for select wave vector values that give  $\mathbf{V} = (a, 0, 0)$ . Construction details are given in the caption. Significantly, Fig. 1 shows that  $V$  can equal  $a$  even when  $\mathbf{V}$  and  $\mathbf{M} \times \mathbf{P}$  are not aligned. The concentrated energy bearers can be marshaled into ensembles.

#### 4. DISCUSSION

Above, I have shown the Lorenz condition can select light-like rays from electromagnetic fields. This permits light mechanism study. Also, its equivalence to charge conservation limits potentials transformation. These aspects are discussed below.

**4.1. Potentials transformation.** Early last century, H. A. Lorentz (1853-1928) made two comments on Maxwell field potentials. First, the Eqs. (4) electric field strength and magnetic induction are unchanged in form for any gauge function,  $\chi$ , that gives new potentials defined by

$$\mathbf{A} = \mathbf{A}_1 - \nabla \chi \quad (15a) \quad \text{and} \quad \Omega = \Omega_1 + \dot{\chi}/a. \quad (15b)$$

Gauge restraints are now widely accepted [10]. Some gauges do not even specify a gauge function. For these, a gauge function further restrains the potentials. The second comment was that Eq. (1), dubbed the Lorenz condition, causes the Maxwell field potentials to satisfy the Eqs. (2) wave equations. This is shown in [11]. Lorentz did not relate these comments. So, the Lorenz condition has been treated as a gauge that can be freely changed. This freedom and wave function potential nonlocality have caused potential reality to be denied. When Eq. (1) is

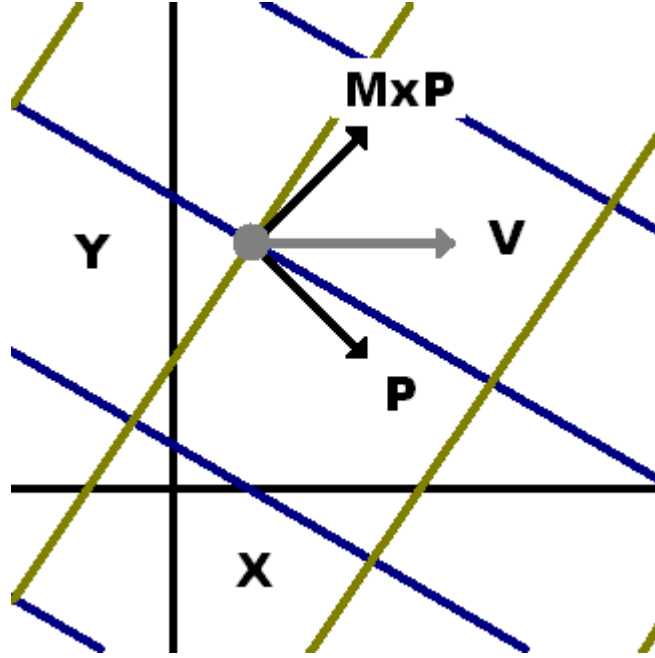


FIGURE 1. This figure depicts a phase and flux directions non-alignment instance. Polarizations are defined by text Eqs. (11) Lissajous potentials with vector potential component wave vectors  $\mathbf{k}_1 = ((\sqrt{265} - 3)/16)^{1/2}, -\sqrt{3}/8, 0$  and  $\mathbf{k}_2 = (1/\sqrt{2}, \sqrt{3}/2, 0)$ . For these potentials the text Eq. (13) phase velocity,  $\mathbf{V}$ , equals  $(a, 0, 0)$ . The hatching represents constant vector potential x- and y-component values at phases  $\phi_1 = -7.60 + 2\pi n$  and  $\phi_2 = 2.55 + 2\pi m$ . These travel with wave speed  $a$  in their respective wave vector directions. The Lissajous periodicities have the relative value  $(\omega_1/\omega_2)^2 = (k_1/k_2)^2 = (\sqrt{265} + 3)/32 \approx 0.60$ . The text Eq. (16a) electric polarization  $\mathbf{P}$  at  $(\phi_1, \phi_2)$  has components  $\mathbf{P}_1$  normal to  $\mathbf{k}_1$  and  $\mathbf{P}_2$  normal to  $\mathbf{k}_2$ . These components depend independently on the  $\mathbf{k}$ 's,  $\phi$ 's and vector potential component magnitudes to give a composite polarization  $\mathbf{P}$  and flux  $\mathbf{M} \times \mathbf{P}$ . Both  $\mathbf{V}$  and  $\mathbf{M} \times \mathbf{P}$  change magnitude and direction as the  $\mathbf{k}$ 's are independently changed. But  $\mathbf{M} \times \mathbf{P}$  can be brought into alignment with fixed  $\mathbf{V}$  by changing the vector potential component relative magnitudes and, equivalently for the Eqs. (11) potentials, the  $\phi$ 's. This alignment is required to keep a ray from dissipating.

charge conservation, as I have shown above that it is, these comments are coupled. As charge conservation, Eq. (1) is a basic law. With this, in Sec. 2 I have shown the Eqs. (2) wave function potentials give the Eq. (6) field equations with Maxwell form. This is the second comment converse. Thus, Maxwell fields must always have wave function potentials. The potentials can be local, nonlocal or mixed. Further, as a basic law, Eq. (1) can not be freely changed.

When the original potentials are sourced wave functions Eqs. (15) resolve to three Lorenz classes that need not have the gauge function form. First, the new potentials are not wave functions. Second, the new potentials are wave functions with changed source values. Third, the new potentials are wave functions with unchanged source values. In the first case the Lorenz condition will not apply. Then, charge will not be conserved and the potentials will not propagate with a wave speed. Both must be spurned. The latter, because tests in [12, 13, 14, 15] show longitudinal electric fields to propagate with finite speed. The last two cases will conserve charge if the Lorenz condition persists. This persistence will assure Lorenz field equations in which charge and current density are deemed observables that produce potentials and fields yielding emergent light-like waves. These conserve charge progressively as described in Sec. 3.1. Further, localized energy is conveyed on ray forming phase points as described in Sec. 3.2. For gauge transformations, persistence requires the Lorenz gauge,  $\square_a \chi \equiv \nabla \bullet \nabla \chi - \overset{\circ\circ}{\chi}/a^2 = 0$ . It suppresses the polarizations and, thus, their dependent, emergent rays.

**4.2. Light mechanization.** In the late eighteen hundreds, H. von Helmholtz (1821-94) tried to unite electromagnetic theories [16]. To this end he based his concept on electric and magnetic polarization. From this he obtained wave equations for a homogeneous medium. His transverse waves have speed  $c/\sqrt{\epsilon\mu}$ . Here  $c$  is the vacuum light speed. Only difficult, precision measurements could complete the theory, because his longitudinal wave speed has any value greater than or equal to zero. Unlike Helmholtz waves, Lorenz waves are simply transverse, because Eq. (6b) gives  $\nabla \bullet \mathbf{P} = 0$ .

To promote his concept, Helmholtz issued a challenge to measure a coupling between electromagnetism and dielectric polarization. His former student, H. Hertz (1857-94), later claimed the prize. He then went on to observe dipole radiation reflection and interference. Based on this Hertz concluded that polarization propagation is like vacuum light [17, pp. 19 and 122-3] and [18]. Hertz's dipole field [4, 17, 18] has radial, transverse wave emergence in the far field. At intermediate distances the waves have greater than light speed that approaches light speed in the far field. These waves change from longitudinal to transverse as the radial direction changes from dipole length to dipole equator. Hertz reconciled these properties in the equatorial plane by observing strobed interference between free air and straight wire waves [17, pp. 150-5]. His and recent [19] reports suggest light structure may be open to study. Antiphased fields in [19] may represent an Eq. (6d) Ampere law based, magnetoinductive internal structure [2].

For vacuum polarization waves Eq. (8a) takes a simple form. By the Gauss theorem, it represents an equality between the temporal energy change in a volume and the energy flux through its surface. For monochromatic waves,  $\mathbf{M} \times \mathbf{P}$  can be written using the Hertz analogy as  $h\nu \mathbf{f}$  where  $h\nu$  is photon energy and  $\mathbf{f}$  is photon flux with coherence length inversely related to monochromaticity departure [20]. This dependence means that the photon power density must approach zero as the coherence length becomes very large for monochromatic photons. The compact, quantum particle photon concept is untenable in this limit. The concept is further threaten by confounding photon size with wavelength. This problem is revealed by the Table 1 benchmarks. There the lowest energy photons have a wavelength greater than the Earth orbit radius. These conflicts are homologized in [21] by

setting a hypothetical photon energy density equal to a flux magnitude divided by the energy transfer speed.

TABLE 1. Some Vacuum Photon Properties

Energy $h\nu$	Frequency $\nu$ Hz	Wavelength $\lambda$ cm	Energy $h\nu$	Frequency $\nu$ Hz	Wavelength $\lambda$ cm
1 GeV	0.241E24	12.4E-14	1 $\mu$ eV [17]	0.241E9	12.4E1
1 MeV	0.241E21	12.4E-11	1 neV	0.241E6	12.4E4
1 keV	0.241E18	12.4E-8	1 peV	0.241E3	12.4E7
1 eV	0.241E15	12.4E-5	1 feV	0.241	12.4E10
1 meV	0.241E12	12.4E-2	1 aeV [19]	0.241E-3	12.4E13

For energy,  $h$  is Planck's constant. Electron rest mass equals 0.5 MeV, visible light at 5000 Å equals 2.48 eV and cosmic microwave background radiation at 3 K equals 0.26 meV. Atomic nucleus radii are about E-12 cm, atomic radii are about E-8 cm, Earth radius is 6.38E8 cm and Earth orbit radius is 1.5E13 cm. Solar radiant energy flux at Earth is 8.58E21 eV/(s m<sup>2</sup>) with an energy distribution that should be appropriate for the 5780 K effective sun temperature. The H. Hertz, *Electric Waves*, D. E. Jones, trans. (Dover Pubs., Inc., NY, 1962) and P. J. Chi and C. T. Russell, "Phase skipping and Poynting flux of continuous pulsations," J. Geophys. Res. **103**:A12, 29479-29491(1998) citations attempt internal structure study.

When phase point motion and wave flux are not aligned, flux normal to the phase point motion would force ray dissipation. This is like saying that all light rays are electromagnetic, but not all electromagnetic waves are light rays. Failure to recognize this has prevented light-like rays from being found in electromagnetic fields to help describe light behavior in optics and photography [7,8,9]. Synchrotron light emitted as rays by high speed electrons in a circular orbit supports this. These rays are attributed to the radial acceleration not the periodic linear acceleration required to maintain the electron energy. Their presence in the electric field has not been shown [22, 23, 24]. However, one unconfirmed report [25] finds them to be electrically polarized in the electron orbit plane like the Sec. 3.2 phase directed polarization waves.

Although phase independence is compelling, its nonexistence would support treating rays as having the closely bound potentials described in Sec. 3.1 above. In this limit energy should still be borne progressively by charge conserving phase points. Even so, phase independence is a hidden variable whose consequence is unintuitive. Whether electromagnetic energy localization to phase points is consistent with quantum statistics should be examined elsewhere, because it has special features to help model the standard quantum oscillators. The points are defined by Lissajous potentials. They bear a fixed flux at constant speed. They vanish where either charge cannot be conserved or flux and phase are not aligned. Individually, they do not bear oscillations. But they can be marshaled into Eq. (20), Piekara bead-chain, flux magnitude beads. These features provide a new means to help describe light generation. If flux and phase alignment were required for light generation, its low intrinsic likelihood would predict a small efficiency. One challenge is light from atoms. Its study could help increase laser output when atoms are aligned by shell structure.

## 5. CONCLUSION

I have shown that if Lorenz had published field equations electromagnetism as we know it today would have a solid, delay based etiology. We would have Lorenz condition equivalence to charge conservation, light-like ray emergence from fields and energy conveyance by field phase points. Based on this I propose that the terms "Lorenz condition" and "Lorentz condition" be retained. The Lorentz condition would be only a potentials transformation. The Lorenz condition would express charge conservation in a form left unchanged by potentials transformation, Lorenz covariance. Further, the light-like rays that convey localized energy in Lorenz fields escape discovery in modern Maxwell fields. So, they may aid photon mechanization.

## APPENDIX

For the Eqs. (11) potentials, Eqs. (5) gives

$$\mathbf{P} = \left( \frac{k_{2x}k_{2y}}{k_2} \cos \phi_2 - \frac{k_{1y}^2}{k_1} \cos \phi_1, \frac{k_{1x}k_{1y}}{k_1} \cos \phi_1 - \frac{k_{2x}^2}{k_2} \cos \phi_2, 0 \right), \quad (16a)$$

$$\mathbf{M} = (0, 0, k_{2x} \cos \phi_2 - k_{1y} \cos \phi_1) \quad \text{and} \quad (16b)$$

$$\begin{aligned} \mathbf{M} \times \mathbf{P} &= (k_{2x} \cos \phi_2 - k_{1y} \cos \phi_1) \times \\ &\times \left( -\frac{k_{1x}k_{1y}}{k_1} \cos \phi_1 + \frac{k_{2x}^2}{k_2} \cos \phi_2, \frac{k_{2x}k_{2y}}{k_2} \cos \phi_2 - \frac{k_{1y}^2}{k_1} \cos \phi_1, 0 \right). \end{aligned} \quad (16c)$$

Taking  $\phi_1 = \phi_2 = \phi$  gives the simple harmonic polarizations and flux

$$\mathbf{P} = \cos \phi \left( \frac{k_{2x}k_{2y}}{k_2} - \frac{k_{1y}^2}{k_1}, \frac{k_{1x}k_{1y}}{k_1} - \frac{k_{2x}^2}{k_2}, 0 \right), \quad (17a)$$

$$\mathbf{M} = \cos \phi (0, 0, k_{2x} - k_{1y}) \quad \text{and} \quad (17b)$$

$$\mathbf{M} \times \mathbf{P} = (k_{2x} - k_{1y}) \cos^2 \phi \left( -\frac{k_{1x}k_{1y}}{k_1} + \frac{k_{2x}^2}{k_2}, \frac{k_{2x}k_{2y}}{k_2} - \frac{k_{1y}^2}{k_1}, 0 \right) \quad (17c)$$

having bead-chain [21] flux squared magnitude

$$|\mathbf{M} \times \mathbf{P}|^2 = (k_{2x} - k_{1y})^2 \left[ k_{2x}^2 - 2 \frac{k_{2x}k_{1y}}{k_1k_2} (k_{2x}k_{1x} + k_{2y}k_{1y}) + k_{1y}^2 \right] \cos^4 \phi. \quad (18)$$

When  $\mathbf{k}_1 = \mathbf{k}_2 = \mathbf{k} = (k_x, k_y, 0)$ , the polarizations further simplify to

$$k\mathbf{P} = (k_x - k_y) \cos \phi (k_y, -k_x, 0) \quad \text{and} \quad (19a)$$

$$\mathbf{M} = \cos \phi (0, 0, k_x - k_y) \quad (19b)$$

with the flux having direction  $\mathbf{k}$  and magnitude

$$|\mathbf{M} \times \mathbf{P}| = (k_x - k_y)^2 \cos^2 \phi. \quad (20)$$

This flux is highly anisotropic with maximum values for  $k_x = -k_y$  and null values for  $k_x = k_y$ .

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